Metal nanoparticles and patterned dielectric on InGaN/GaN LEDs: Combining plasmonic and light extraction enhancement.

Fadil, Ahmed; Ou, Yiyu; Iida, Daisuke ; Ou, Haiyan

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Fadil, A., Ou, Y., Iida, D., & Ou, H. (2015). *Metal nanoparticles and patterned dielectric on InGaN/GaN LEDs: Combining plasmonic and light extraction enhancement.*. Abstract from 3rd International Conference on Light-Emitting Devices and Their Industrial Applications, Pacifico Yokohama, Japan.

Metal nanoparticles and patterned dielectric on InGaN/GaN LEDs: Combining plasmonic and light extraction enhancement

A. Fadil,[1,*] Y. Ou[1,2], D. Iida,[3] and H. Ou[1]

[1] *DTU Fotonik, Technical University of Denmark, 2800 Lyngby, Denmark*

[2] *Light Extraction Aps, 2800 Lyngby, Denmark*

[3] *Department of Applied Physics, Tokyo University of Science, 125-8585, Tokyo, Japan*

[*] *afad@fotonik.dtu.dk*

The InGaN/GaN material system has made high-brightness blue and green light-emitting diodes (LEDs) a possibility, and paved the way for commercialization. Although blue LEDs have efficiencies reaching above 80 %, moving towards the green by increasing the indium composition significantly reduces the efficiency due to quantum-confined Stark effect [1]. There are two basic ways of mediating the low efficiency of green LEDs, which are by increasing the light extraction efficiency (LEE) and the internal quantum efficiency (IQE). The LEE can be improved by nano-patterning the surface through which light is emitted, and one way of improving the IQE involves the use of metallic nanoparticles (NPs) [2].

In this work, we propose a method to improve LEE by using dielectric coating on the p-GaN surface and fabricating nanostructures on the dielectric. This way we can achieve improved photoluminescence (PL), which is expected to originate from the reduced refractive index mismatch and increased critical angle from a patterned surface. Fabricating Ag NPs on p-GaN also shows improved PL emission due to surface plasmonic coupling. By combining the patterned surface and surface plasmonic coupling, i.e., using a patterned dielectric (SiN) between the Ag NPs and the semiconductor an even higher PL enhancement is obtained, which is believed to be coming from increased LEE and IQE. Another advantage of this design is the achieved PL enhancement from the p-GaN side in addition to the sapphire side. Usually the emission enhancement from Ag NPs is only observed from the sapphire side due to the localized surface plasmon modes being confined to the metal-substrate interface and therefore radiate towards the substrate. By considering the transmittance spectra of Ag NPs on SiN, a blue-shift of the resonance dip is observed relative to the case of Ag NPs on p-GaN. A further blue-shift of the plasmonic resonance is observed with Ag NPs on a patterned SiN. This is expected to be due to a reduced effective refractive index relative to the index of the bare SiN.

This research was supported by the Danish Council for Strategic Research (0603-00494B).

[1] T. Takeuche *et al*., "Quantum-Confined Stark Effect due to Piezoelectric Fields in GaInN Strained Quantum Wells," *Jpn. J. Appl. Phys.*, **382**, L382 (1997).

[2] A. Fadil *et al*. "Surface plasmon coupling dynamics in InGaN/GaN quantum-well structures and radiative efficiency improvement." *Sci. Rep*. **4**, 6392 (2014).

Supplementary information

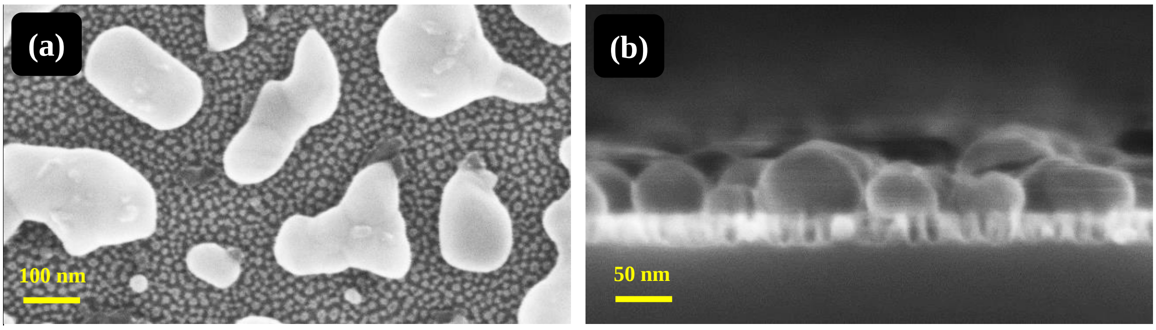

Figure 1: Scanning electron microscopy images of Ag NP formation on SiN nanopillars. (a) Top and (b) cross-sectional view.

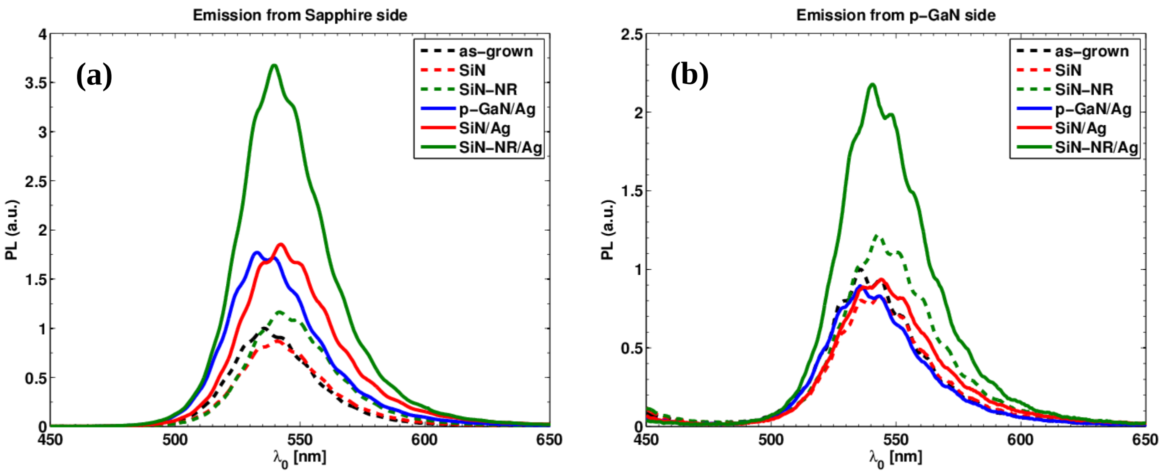

Figure 2: PL spectra from sapphire side excitation, where the bare SiN and nanopillar SiN (SiN-NR) coated p-GaN surface without Ag NPs are also included. PL emission from (a) sapphire and (b) p-GaN side.

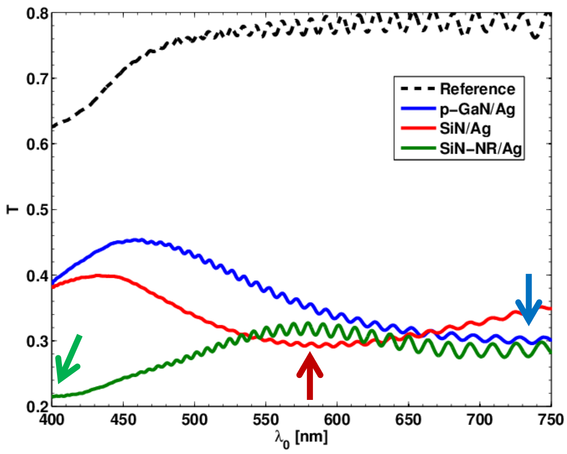

Figure 3: Transmittance spectra of samples with Ag NPs on p-GaN, SiN and SiN nanopillars. Arrows indicate positions of metallic resonances.